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SEWAGE PURIFICATION IN AMERICA.

(Continued from vol. XXVIII., p. 611.)

Pullman, Ill.

The sewage farm at Pullman, like Pullman itself, has attracted much attention from engineers and others. A detailed description of the farm and the sewerage system was given over ten years ago in this journal,* less than a year after it was put in operation. Information regarding the present status of the sewerage system and sewage farm and other facts of interest have just been furnished us by Mr. Duane Doty, C. E., engineer for the Pullman company. This information has been combined with such of the matter previously published as is necessary to make the present article complete and intelligible in itself. Mr. Benezette Williams, C. E., was engineer for the whole system, and Mr. E. S. Chesbrough, M. Am. Soc. C. E., was consulting engineer.

Pullman is situated upon the west shore of Lake Calumet, 14 miles south of the Chicago Court House, where the Pullman interests have about 4,000 acres of land. It is reached by the Illinois Central Ry., and by recent annexation now forms a part of the city of Chicago. Lake Calumet is 3½ miles long by 1½ miles in width, and connects with Lake Michigan by the Calumet River. According to Mr. Williams' description in 1882, Lake Calumet is from 1 to 8 ft. deep, and connects with the Calumet River by a small channel. With varying stages of water the lake discharges into the river or water from the river into the lake.

The land upon which the city stands is blue clay, 90 ft. in depth, resting upon lime rock, and its surface is from 9 to 20 ft. above the lake level.

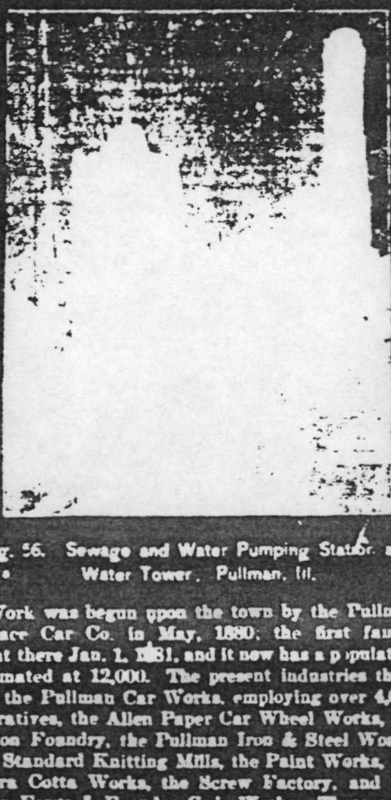


Fig. 56. Sewage and Water Pumping Station and Water Tower, Pullman, Ill.

Work was begun upon the town by the Pullman Palace Car Co. in May, 1880, the first family went there Jan. 1, 1881, and it now has a population estimated at 12,000. The present industries there are the Pullman Car Works, employing over 4,000 operatives, the Allen Paper Car Wheel Works, the Union Foundry, the Pullman Iron & Steel Works, the Standard Knitting Mills, the Paint Works, the Terra Cotta Works, the Screw Factory, and the Drop Forge & Foundry Co.'s Works. These various industries, with the car works, employ a total of about 5,800 operatives.

Oct. 18, 1881, the sewerage system was put in operation by starting the sewage pumps. Lake Calumet not being a suitable body of water to receive the sewage of Pullman, and an outlet to Lake Michigan requiring pumping through 6½ miles of pipe, it was decided to purify the sewage by broad irrigation, supplemented by intermittent filtration.

The separate system of sewerage was adopted to save expense and insure better results at the disposal works. The latter part of October 1[illegible] there had been laid 16,230 ft. of brick and 140,[illegible] ft. of vitrified pipe storm sewers, the latter [illegible]cluding drains for storm water from over 1,[illegible] tenements. The brick storm sewers are laid in [illegible] middle of east and west alternate streets [illegible] discharge into Lake Calumet. The pipe st[illegible] sewers are of the following sizes and lengths:

Size.	Ft.	Size.	Ft.
18-in.	1,826	9-in.	14[illegible]
15-in.	16,222	6-in.	71,[illegible]
12-in.	18,464	4-in.	27,[illegible]
Total			140,[illegible]

To Oct. 22, 1892, the extent of the vitrified p[illegible] sanitary sewers, by sizes, was as follows:

Size.	Ft.	Size.	Ft.
18-in.	4,340	9-in.	7,2[illegible]
15-in.	3,170	6-in.	32,[illegible]
12-in.	1,220	4-in.	31,[illegible]
Total			79,[illegible]

Manholes are placed from 140 to 165 ft. apart and on the sanitary sewers have perforated covers, provision being made for the catching of the [illegible] which passes through the perforations.

The 9, 12, 15 and 18-in. sanitary sewers are flushed directly from the water mains. Additional flushing is secured, or was in 1882, from automatic flushing basins which receive all but the water closet wastes of several houses and discharge it by means of siphons. The basins also act as grease traps, the siphons being especially designed to remove grease and scum from the basins.

Sewage is received in a 300,000-gallon reservoir, 60 ft. in diameter and 15 ft. deep, located beneath the water-works tower. The outlet sewers at the reservoir are about 16 ft. below the general grade of Pullman.

The reservoir is ventilated by means of eight flues, each 165 ft. high, lined with 12-in. sewer pipe, built into the buttresses of the water tower, and also by a 20-in. pipe leading to the chimney of the car shops.

Both the sewage and water-works pumps are placed about 10 ft. below the ground surface on a masonry floor, supported by piers, covering the sewage reservoir. There are two 2,500,000 gallon pumping engines, built by the Cope & Maxwell Manufacturing Co., of Hamilton, O. The pumps have special valves, described in our issue of June 17, 1882. Connected with the force main at the pumps is a stand-pipe with an overflow 54 ft. and a second, 90 ft. above datum (not defined). These overflows connect with the reservoir, so if all the outlets at the farm were by accident closed without the pump being stopped no accident could occur. A 20-in. force main about three miles long leads to the sewage farm.

The amount of sewage pumped yearly from the reservoir to the sewage farm has been as follows:

Year.	Gallons
1882	211,020,100
1883	358,374,420
1884	443,815,480
1885	468,102,120
1886	472,748,080
1887	573,700,640
1888	585,607,720
1889	602,250,000
1890	657,001,980
1891	617,664,000
1892 (9 months)	513,996,090

The amount given for the nine months of 1892 is at the annual rate of 685,328,080 gallons.

The cost of operating one pump for 20 hours and pumping 1,800,000 gallons of sewage is, given by Mr. Doty, as follows:

Cost of coal used	$1.73
Cost of oil and waste	.57
Engineer's wages	3.75
Total	$6.05

This is at the rate of $3.36 per million gallons.

Fig. 56 is a photographic view of the tower and Fig. 57 a vertical section through half of it. This unique structure, with its many uses, is 68 ft. square at the base, changes to octagonal form, as shown by the view Fig. 56, and is 195 ft. high to the base and 210 ft. to the top of the flagstaff. The foundation extends nearly 40 ft. below the ground surface, where it rests on a very hard blue clay.

The tower was built to afford elevation for the water tank at its top, which is of boiler iron, 55 ft. 10 ins. in diameter, 30 ft. 1 in. deep, and has a capacity of about 550,000 gallons. The tank is supported by iron trusses, resting on four wrought iron columns, which extend to the foundations.

In December, 1890, the second floor of the tower

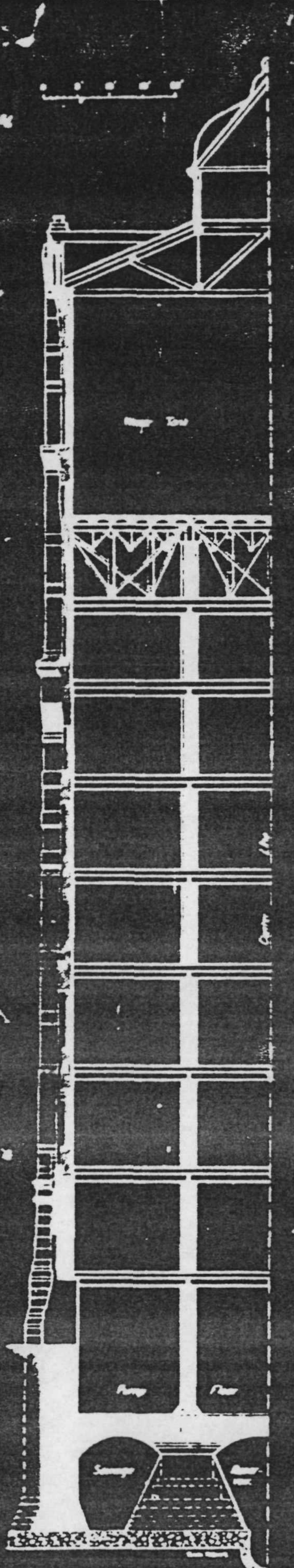


Fig. 57. Section Through Tower.

* Engineering News, June 17, 1882. The description was slightly condensed from a paper on "The Pullman Sewerage," by Benezette Williams, C. E., engineer for the system, read before the Western Society of Engineers, June 5, 1882, and published in the "Journal of the Association of Engineering Societies," vol. I., pp. 311-318.

was occupied by the electrical department of the Pullman car shop; the third and fourth floors were used for making mirrors and other glass work, the fifth floor was occupied by a branch of the paint department, and the floors above were used for light storage, elevators being provided to reach the different stories.

The building at the right of the tower contains the Corliss engine which furnished power for Machinery Hall at the Centennial Exposition at Philadelphia in 1876. This engine has been in operation at the Pullman Car Works since April 5, 1881.

The accompanying illustration, Fig. 58, shows the screening tank and automatic regulating valve at the farm end of the force main. The following description of these devices is from Mr. Williams' paper, mentioned above:

The farm end of this main connects with a closed screening tank, by means of which all material that will not pass through a screen of ½-in. mesh is intercepted. The tank is 6 ft. in diameter and 24 ft. long, made of ½-in. boiler iron. It is set vertically with its lower end high enough above the floor to admit of a wagon being driven under it. The material intercepted by the screen is lodged in the lower part of the tank, from which it is removed from time to time.

On leaving the tank the sewage passes through a pressure regulating valve, which limits the pressure that comes upon the pipes leading to the fields to about 10 lbs. As an additional precaution against high pressure, an overflow pipe is provided, which will absolutely,

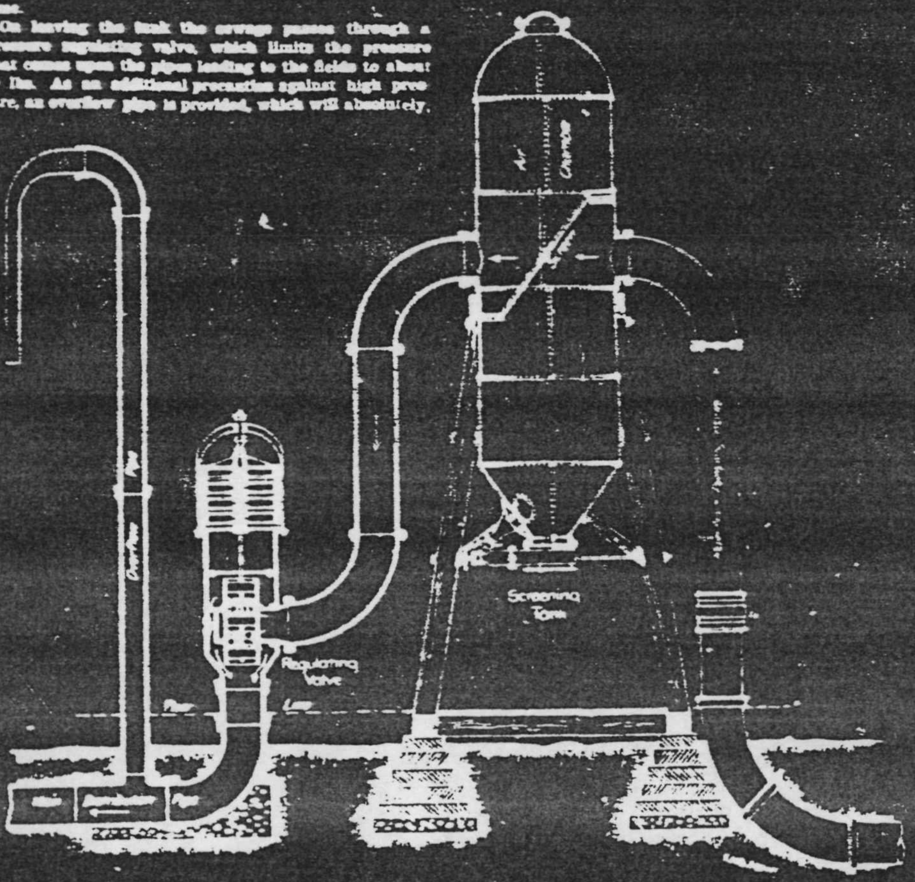


FIG 58. SECTION THROUGH SCREENING TANK AND REGULATING VALVE.

under all conditions, prevent the pressure from rising above the limit. This pipe comes into play occasionally when the pumps are started suddenly, without giving the valve time to act. The valve is purposely made to act slowly, in order to avoid the influence of pulsations in the engines, and irregularities from other causes.

The action of the tank and valve are better understood by an examination of the accompanying drawing (Fig. 58).

A pressure on the interior of the thin steel discs above the valve, raises the plunger and closes the port through which the sewage passes. If the pressure falls, the ports open gently. Vibrations of the valve from sudden changes of pressure are prevented by a plate between the valve and the steel disks, through small holes in which the sewage has to pass in order to increase or diminish the pressure on the discs.

The upper part of the tank above the screen is an air chamber, and answers the usual purpose of such an adjunct in preventing shocks from irregularities in the pumps, or by the sudden stopping of the flow of sewage. The tank and valve are housed in, and can be kept warm to prevent freezing in cold weather.

The reason for introducing the pressure regulating valve between the screening tank and the field is to make it possible to distribute sewage safely through clay sewage pipes under pressure.

The sewage farm embraces 140 acres piped and underdrained for the reception and purification of sewage. All this land can be irrigated, and it is all underdrained. Vitrified pipe from 6 ins. to 1 ft. in diameter, conducts the sewage through the fields. This piping, laid from 4 to 6 ft. deep, and hydrants at convenient intervals of 300 or 400 ft., distributes the sewage over the surface.

The underdrains in the farm are of 3 and 4-in. farm tile, laid in rows 50 ft. apart.

There are also 10 filter beds about an acre each, formed by earth embankments, and underdrained with lines of farm tile said to be 2 ft. apart.

Mr. Doty states that the use of sewage for growing crops depends upon the season. In dry seasons it is freely used with the vegetation needing it most. Irrigation is practised at all seasons, and the watery filter through the soil as well in the winter as during the summer. The crops which have so far proved most successful are onions, potatoes, cabbages, celery, beets, parsnips, carrots, sweet corn, and squashes. Potatoes are the least successful crop, celery, asparagus, and cauliflower coming next in order as not growing so well on this farm. Properly cultivated, twice as much can be raised on land irrigated with sewage as upon adjacent land unirrigated; and with onions the results are still better. It is stated that there never has been trouble with deposits of sludge upon the surface of the farm.

Mr. Doty states that the only analysis of Pullman sewage and effluent in his possession was made in the office of the Massachusetts State Board of Health, Nov. 30, 1887, with results as follows, analysis of water from the farm well being also given for comparison:

	Ammonia. Free.	Ammonia. Albuminoid.	Chlorine.	Nitrogen.
Pure sewage	2.3000	.3200	1.98	None
Filtered sewage from manhole on filter bed	.2000	.0680	2.81	1.500
Filtered sewage from mouth of main underdrain	[illegible]	[illegible]	2.75	[illegible]
Water from farm well	[illegible]	[illegible]	1.73	[illegible]

The effluent from the farm passes through the underdrains into Lake Calumet.

Regarding what proportion of the sewage is used for broad irrigation and what proportion is passed through the filter beds, and as to whether the sewage is always purified before passing into Lake Calumet, Mr. Doty sends the following, under date of Nov. 28, 1892, which he gives as "the language of the superintendent of the farm:"

The sewage when not needed upon the fields of the farm is run onto the filter beds, and these filter beds are plowed up four or five times a year so as to loosen the soil and expose as much of it as possible to the air. At times, all the sewage is used upon the farm, and in wet weather not more than half of it. Some seasons have taken all the sewage upon the fields. At rare intervals only when it has been necessary to clean the receiving tank at the farm end of the iron main, is raw sewage run into Calumet Lake and then for very brief periods and not enough of it to do any harm.

That this statement from the superintendent of the sewage farm is not in accord with observations made at Pullman by five different persons is shown by the statements given below. The remarks of Mr. Allen in the report mentioned and a conversation with Mr. Hazen, together with the fact that the Pullman plant has for many years been widely known and cited as a successful example of American sewage farming, led to a somewhat thorough investigation of the subject, the results of which are herewith presented and need no comment further than the remark that because profit is put before purification at Pullman, it does not follow that sewage purification by means of broad irrigation is in any degree a failure, it often being a useful method or adjunct of sewage disposal.

Mr. Geo. H. Benzenberg, M. Am. Soc. C. E., City Engineer of Milwaukee, Wis., wrote as follows on Nov. 21, 1892:

I have not been at Pullman for a number of years and hence cannot give you any information whatever as to what they are doing there now, but I know that as early as previous to 1887, a large amount of crude sewage was run into Lake Calumet. This I found to be the fact upon a visit to the farm, and which finally the superintendent admitted and excused by saying that it was necessary in order to save the crops. The sewage was being run in a large open ditch, covered by bushes growing on each side, from near the farm to the lake. As to their success in disposing of sewage by intermittent filtration, I am not at all acquainted.

About a month after the date of Mr. Benzenberg's letter, Mr. Rudolph Hering, M. Am. Soc. C. E., of New York, corroborated the above by stating that he visited the farm in 1886 and also in 1887. He found that a large amount of crude sewage had been run into Lake Calumet just prior to his visit, as the large open ditch leading from the farm to the lake was still partially filled with crude sewage. The superintendent likewise admitted to him that it was necessary to do this occasionally to save the crops.

In his report on the "Sewage Disposal of Worcester" Mr. C. A. Allen, M. Am. Soc. C. E., City Engineer of Worcester, Mass., describes a visit to the Pullman sewage farm, made January, 1887, as follows:

The farm has an area of about 160 acres, nearly all of which is devoted to irrigation, there are 10 acres, however, set apart for a filtration area, this being thoroughly underdrained, the drains being about 2 ft. apart.

Upon the day of our visit it was quite warm, the thermometer registering 60° F. We found that the sewage was being discharged upon the filtration area, the first section of which was covered with sludge to a depth of about a foot. The sewage was running over this, to the second section, which was partially covered with ice, and then over the remaining area, which was entirely covered with ice, and was finally discharged into the effluent trench without having been filtered in the least.

The entire area was completely covered with sewage, and there was evidently no filtration taking place, as about the same quantity passed off at the lower end of the beds as was discharged upon the upper end.

The manager of the farm was away, but we were given the following facts by his assistant, which we subsequently verified:

The farm is run for the purpose of making money.

the purification of the sewage being a secondary consideration.

During the summer months when vegetation has received all the sewage it will bear, it is simply turned into Lake Calumet in its crude state.

We were told that not a particle of sewage has been applied to the farm proper this winter, it all having been simply passed over the area as already described.

What Mr. Benzenberg, Mr. Hering and Mr. Allen saw and learned in 1886 and 1887, and more, was still to be seen and learned in 1891, according to a letter recently received from Mr. Allen Hazen, Chemist in Charge of the Lawrence Experiment Station of the Massachusetts State Board of Health. Mr. Hazen states the condition of the filter beds, and gives a mechanical analysis of the surface soil of the filter beds. His letter is as follows:

I visited the Pullman sewage farm in October, 1891. The superintendent was absent, and I was shown about by a man who had worked on the farm for some years. He told me that with the application of sewage, worms developed in the soil and destroyed the crops, and for this reason no sewage had been applied for two or three years. Large quantities of horse manure from Chicago stables are applied to the land, but no sewage whatever. After broad irrigation was abandoned, so-called intermittent filtration was tried on ten acres of soil on which no crops were grown.

The filter was not in use at the time of my visit, nor did it have the appearance of having been used. My guide thought that it was at least a month since any sewage had been applied, and a much longer time since any considerable quantity had been treated. The sewage of the entire town was being turned directly into Lake Calumet, from which quantities of ice for Chicago are cut.

A sample of the surface soil of the filter had the following mechanical analysis:

Finer than .24 mm.		67 %
" " .12 "		42 "
" " .06 "		28 "
" " .03 "		16 "
" " .01 "	organic	06 "

Albuminoid ammonia, 225 parts in 100,000.

The analysis shows the material to be very much finer than the sands successfully used in Massachusetts, and it would hardly be possible to put upon it, with good results, any large volume of sewage.

On Nov. 21, 1892, a representative of this paper visited Pullman. Neither the superintendent or foreman of the farm were to be found. The building which covers the screening tank at the end of the iron force main is represented as having "a decidedly shiftless and unused appearance,"—the interior being used as a storage room for plows, cultivators, harrows, including the part originally designed for loading wagons when cleaning out the screening tank. Sewage was found to be flowing through the ditch leading to Lake Calumet. This ditch is about 4 ft. wide, 2½ ft. deep, and ¾ miles long. Located on Lake Calumet are two large ice houses belonging to Swift & Co.

The only person about, who said that he was a time-keeper, stated that the matter flowing in the ditch was the sewage as it came from Pullman and was all the sewage from the city.

A pair of triple-expansion condensing Corliss engines of 2,400 HP. each, has been erected at the new mill of the Fall River Iron Works Co. by the Corliss Steam Engine Co., of Providence, R. I. The cylinders are 23¼, 39½ and 54 ins. diameter, 5-ft. stroke, and are arranged tandem. The pulley flywheel is 2 ft. diameter, and 15 ft. 4 ins. wide at the face, carrying four driving belts. The weight of the wheel is about 75 tons.

The Channel tunnel question is up again in England, and Mr. Gladstone, who favored the scheme when a member of the House of Commons, is expected as Prime Minister to wield much more influence in pushing the movement. The French are eager for the tunnel, and have driven 6,000 ft. of a large heading from their side. But this very eagerness of the Frenchmen furnishes the strongest argument for Englishmen of the Lord Wolseley type against destroying the insular strength of Great Britain.

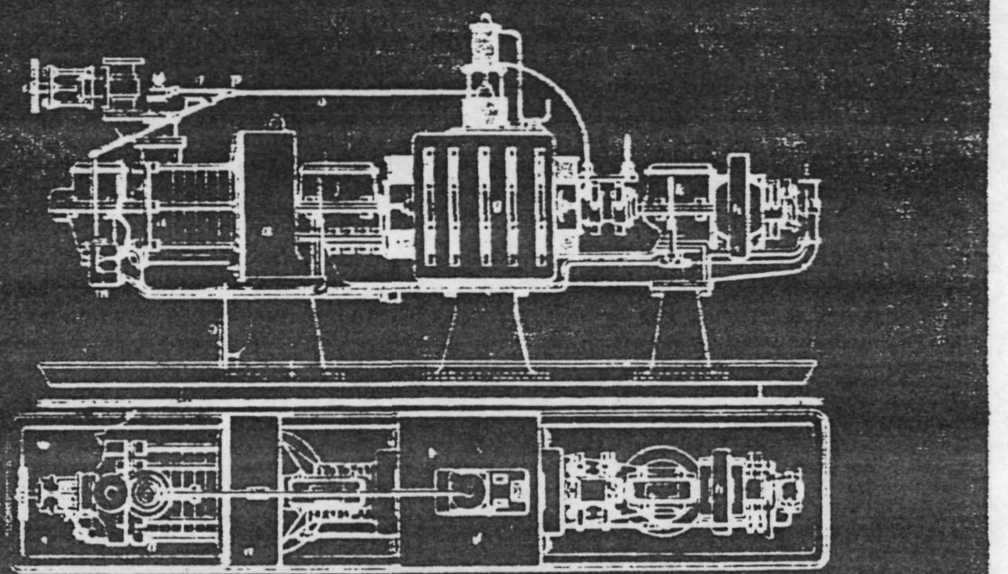
The new Georgia road law, which is now in effect, calls for a capable superintendent of highways, elected by the county commissioners of each county, and requires all men between 16 and 50 years of age to devote not more than 10 days' work annually on the roads, or to pay instead not more than 50 cts. per day. The most essential part of the new system is an ad valorem tax of not more than 0.2% for road purposes.

RECENT DEVELOPMENTS IN STEAM TURBINES.

In our issue of Feb. 27, 1892, we published an exhaustive review of the progress thus far made in the utilization of the expansive force of steam by turbines, describing and illustrating the turbines invented by Mr. J. H. Dow, of Cleveland, O., and by Hon. C. A. Parsons, of Newcastle, England.

The Parsons turbine has been proved so successful and economical that a central station to supply electrical current for the colleges and town of Cambridge, England, is now being equipped entirely with Parsons turbines and direct coupled dynamos. In our former description of the Parsons turbine we reported a test by Prof. J. A. Ewing, F. R. S., of Cambridge University, on a Parsons turbine, in which a steam consumption was obtained as low as 27.6 lbs. (at 95 lbs. pressure) per E. HP. per hour. Prior to the adoption of the steam turbines for the Cambridge station a second series of tests was made by Professor Ewing, and the effect was tried of superheating the steam used. In this manner steam consumptions were obtained but little over 20 lbs. per E. HP. per hour. As an efficiency of about 97% is claimed for the dynamos, this corresponds to about 19¼ lbs. per HP. hour of work actually done by the steam.

The plant at the Cambridge central station consists at present of three independent turbines, direct coupled to alternating dynamos, each machine



FIGS. 1 AND 2. ELEVATION AND PLAN OF PARSON'S STEAM AND ALTERNATING DYNAMOS.

having an output of 120 K-W. per hour (about 160 E. HP.). The station building contains room for three more machines of larger capacity, which will be added as soon as required, and the engine room, only 50 x 35 ft., will then contain a complete engine and dynamo plant with an output of some 1,200 HP. or more. Steam is furnished to the turbines from Lancashire boilers designed for a working pressure of 140 lbs. per sq. in. Jet condensers working down to an absolute pressure of about 1 lb. per sq. in. are attached to the turbines. The speed of the turbines and dynamos is 4,800 revolutions per minute. The alternating dynamo gives 60 amperes of current at 2,000 volts potential, with 80 alternations per second. A separate exciter for the fields is coupled to the same shaft. As there are no reciprocating parts, there is practically no vibration, and each machine rests on rubber blocks with no holding-down bolts. The dynamos have an electrical efficiency of 97.5%.

We condense as follows Professor Ewing's report on tests of the Parsons turbine made last August:

I have to report the results of a further series of trials on the Parsons steam turbine, with the object of testing how far the efficiency has been improved by certain recent changes, and by the use of superheated steam. The same turbine was used in these as in the former trials; but some additional rings of turbine blades were inserted at the high-pressure end to enable it to deal more effectively with pressures up to 115 lbs. per sq. in. (absolute); the vacuum was improved by use of a larger air-pump and by admitting the injection water at a point of the exhaust pipe closer to the turbine, and there was a new governor.

The chief factor in the improvement which has been brought about is, however, the use of moderately superheated steam. The improvement demonstrated by these new trials is very marked. Thus, in the present turbine, with steam superheated 60° F. above the temperature of saturation, the gross amount of feed water is 28.4 lbs. per K-W.-hour when the machine is working

Table I.—General Results of Test.

	Pressure by gage on boiler.	Tempera-ture of steam.	Load in K-W. per hour.	Feed water per hour, lbs. Total.	Per K.W.	Per HP.
	Lbs. per sq. in.	Deg. F.				
Continuous current, moderate superheating.	[illegible]	[illegible]	0.1	[illegible]		
	[illegible]	[illegible]	19.2	700	71.5	[illegible]
	[illegible]	[illegible]	37.0	1,110	41.1	30
	[illegible]	[illegible]	48.2	1,560	32.3	[illegible]
	[illegible]	[illegible]	76.5	2,170	29.[illegible]	[illegible]
	163	[illegible]	102.0	2,900	28.4	21
Continuous current, high superheating.	[illegible]	[illegible]	29.3	1,080	37.5	[illegible]
	[illegible]	[illegible]	40.5	1,190	29.9	[illegible]
	166	[illegible]	78.4	2,170	27.7	[illegible]
Alternating current, moderate superheating.	[illegible]	[illegible]	31.6	1,180	37.3	[illegible]
	97	[illegible]	40.9	1,360	31.1	23.[illegible]
	165	[illegible]	105.2	2,970	28.[illegible]	[illegible]

at full load, and 32 lbs. per K-W. hour at half load. By carrying the superheating further (to 123° F. above saturation), the consumption at full load is reduced to 27 lbs. per K-W.-hour. Comparing these figures with those of the former trial, it will be seen that the consumption of steam has been reduced by about 27%.

What makes these results specially important is the consideration that there is nothing in the construction or working of the turbine to make it likely that the use of superheated steam will be attended by any drawbacks such as have been experienced in engines of the ordinary type. The steam works without lubrication, it comes into contact with no rubbing surfaces and there is no packing to be injured.

A general view of the plant tested is given in elevation in Fig. 1 and in plan in Fig. 2. The turbine case a a contains a series of seven revolving disks, from the surface of which the turbine blades project. They are arranged on each disk in a series of concentric rings. The fixed guide blades stand in spaces between these rings, being carried by annular disks which are fixed to the case. Thus each revolving disk, with its neighboring fixed disk, forms a series of outward-flow

Table II.—Consumption of Feed Water at Various Loads.

Current output in K-W. per hour.	Feed water consumption per hour, lbs. With superheating to about [illegible]° Fahr. Per K-W.	Per E. HP.	With extra superheating to [illegible]° Fahr. Per K-W.	Per E. HP.
[illegible]	48	[illegible]	...	
[illegible]	40	30.1	[illegible]	27.2
[illegible]	29¼	23.7	32	23.9
[illegible]	31	23.8	[illegible]	23.0
[illegible]	[illegible]	22.7	[illegible]	21.3
70	[illegible]	22.0	[illegible]	[illegible]
[illegible]	29	21.8	[illegible]	20.5
[illegible]	28¼	21.3	(27)	(20.1)
100	[illegible]	21.3	(27)	(20.1)

1-8-2-1893 Engineering News - Reco

The engineer, having determined upon the strength and resilience of the material suitable for his purpose, and knowing the deleterious influence of certain elements, and the source of annoyance they may subsequently become in the working of the material after it has left the maker's hands, has a right to limit their presence in the steel to a minimum, besides prescribing the physical tests the steel shall stand. All that is to be considered in this connection is how far the engineer may define both chemical composition and physical qualities, and still leave the manufacturer full scope to meet these requirements without any particular hardship and without enhancing the cost of production. These conditions will probably be best fulfilled by leaving the specifications for analysis incomplete. For instance, suppose the engineer desires steel bars which will have to be subsequently worked into eye-bars. The steel will have to undergo several times reheating, forging and annealing *before* it leaves the mill. We know that silicon acts as a precipitant, and will displace the carbon from its combination with the iron at a red heat. This element must therefore be reduced to a minimum. On the other hand, the presence of maganese in allowable ratio will be desirable rather than otherwise. Moreover, provision must be made for the unavoidable loss in strength consequent upon the several manipulations mentioned. Supposing it is therefore required that the steel of such bars shall have the following physical properties:

Ultimate tensile strength per square inch, pounds	65,000
Elastic limit at, pounds	45,000
Elongation, per cent.	20
Modulus of elasticity not more than, pounds	31,000,000
Cold bending, degrees	180

There will be no particular hardship involved if the specifications require, primarily, that such steel shall show to analysis not more than

Phosphorus	.05
Silicon	.04
Manganese	.50
Sulphur, copper, etc	.00

thus leaving the manufacturer free to vary the carbon percentage in proportion to the other elements, and to the extent necessary to produce or to meet the physical requirements. The finished product out of such steel—supposing all mechanical treatment to have been properly performed—will probably correspond very closely in its results to those obtained with about .30 carbon steel.

While a classification of the product in accordance with the carbon line is probably most easily understood by both engineers and makers in its general meaning, and therefore of great value, to specify simply the carbon percentage without reference to the ratio of the other elements would be worse than useless, while to specify the carbon, and to limit at the same time the percentages of the other elements, would throw the responsibility for the physical properties of the steel entirely upon the engineer.

Speaking in a general way, the range of steels most suitable for bridge construction will be found to lie between from .20 to .50 carbon, and several of these grades may advantageously be employed in the same structure—the lowest grades for members subject to transverse strains and fatigue from shocks, the medium grades for tension members, and the high grades for members under compression. This adaptation of the grade of the steel to the peculiar service for which it is required, constitutes the greatest advantage steel construction possesses, and if properly availed of, leads to the best proportions in the structure.

Much more light than we have at present on this subject is needed ere general rules for chemical composition can be even approximately laid down, and if the intelligent use of steel in structures is to become the rule rather than the exception, it will require cordial co-operation of designer and manufacturer. Only a full knowledge of the other's wants and means will enable each to solve intelligently the problems and elaborate the details pertaining to his field of practice.

BASIS OF STRENGTH.

If all the advantages that steel offers to the designer are to be reaped, our present methods of dimensioning must undergo considerable modification. Foremost among the changes most imperatively demanded is the establishment of a basis for safety factors which shall truly represent the margin or ratio between the working load and the limit of usefulness of the material for structural purposes. This limit is reached at the point at which "permanent set" first takes place—generally, but erroneously, called limit of elasticity—and which might therefore be properly called the "safe strength" of the material. It is being more and more generally recognized among engineers that it is a fallacy to claim for a structure a factor of safety of six, because the maximum recurring stresses in it are about one-sixth of a load, the single application of which would produce failure. It will therefore be well to adopt primarily this "safe strength" or elastic limit as the basis to which the factors of safety are to refer. The knowledge of the ultimate strength is nevertheless to measure, guide the determination of the safety factor, but not by making it the basis for the latter. The intimate relation existing between strength and ductility finds further expression in the gradual increase of the ratio between elastic limit and ultimate strength, as the latter increases, so that this ratio of elastic limit to ultimate strength may be fairly said to be in inverse ratio to the ductility of the material. Now, the greater the range of elasticity in a material, the more ample warning it gives of its failing strength, and vice versa. Therefore this ratio of elastic limit to ultimate strength may be used as a guide in the quantitative determination of the requisite factor of safety for a given structure or its different members. For instance, referring to the "safe strength" or elastic limit as a basis, a factor of 2 will probably be found quite sufficient in cases where this ratio of elastic limit to ultimate is as 1 : 2; but where we find this ratio larger, we shall also find a corresponding decrease in the ductility of the material, hence less warning of impending failure, and must therefore adopt a correspondingly larger safety coefficient.

Another point for consideration is the fact that the ratio of thickness to width exerts a considerable influence upon the tensile resistance. This will require to be taken into account in dimensioning very wide and comparatively thin eye-bars, and also in accepting test results of small specimens as a criterion of the strength of plates. In general, specimen tests will always give results from 10 to 15 per cent. in excess of what the full-sized members will show.

Altogether, dimensioning in steel, while it affords the designer exceptional opportunities for display of engineering skill, requires also careful consideration of the susceptibility of the material to treatment, and hence no attempt ought to be made to establish a uniform basis of strength, as has been done in iron construction, nor could any such attempt be fruitful of anything else than confusion and obstruction. *Designers in steel will have to* establish and to change constantly the basis of strength calculation with the adaptation of the greatest number of physical properties to the particular structure under consideration.

PHYSICAL TESTS.

To prescribe tests in such a manner that they shall be at once exhaustive indications of the characteristics of the material, and yet not become burdensome, is no easy task. It may be accepted as a general rule that specimen tests are of small practical value outside of the field of scientific investigation, and if made in sufficient number to become really serviceable in the course of a construction, their preparation in lathe and planer will take a great deal of time, and be a considerable item of expense. Of course, they cannot be altogether dispensed with, and are in some cases even the readiest means of settling a question at issue. For instance, if it is suspected that the steel has roll-hardened, or that it is burnt, duplicate specimens, one tested as it comes from the rolls, the other after annealing it, will tell a short, but very effective, story.

For the determination of modulus of elasticity carefully prepared specimens ought to be used, and the writer would call attention right here to the vital importance of this so generally neglected factor in strength determinations. Full-sized eye-bars are readily tested up to $1\frac{1}{4}$ to $1\frac{1}{2}$, the maximum stress they are dimensioned for; this is fully within the elastic limit, and ought, therefore, to occasion no loss of material, and give at the same time definite indications of both strength and workmanship. For plates and angles the cold-bending test—before and after annealing—is the easiest of application, and, after all, the most decisive.

Where large presses are available, transverse tests of beams within the elastic limit and up to double the amount of calculated or allowed deflection, are readily and quickly made. The cutting of specimens from web and flange for tests is slow and expensive work, and tells but little. The drop test (under a hammer in guides and with equal heights of fall) will give very conclusive data, especially if comparison is made between the behavior of annealed and unannealed beams. Compression tests of small specimens are almost valueless, unless at least the proportion of length and diameter in the full-sized member is closely reproduced. An exhaustive series of steel-column tests is most needed at the present moment. Testing, of course, must include the effects of punching, shearing and annealing, but very few specimens, even in a large structure, will suffice for very good conclusions, if the other and preceding tests have been carefully made. Testing, without taking into account every detail that exerts influence, is apt to lead to serious errors, and is merely a useless waste of time and money.

INSPECTION.

Every engineer knows that no specifications were ever drawn for an important structure from which more or less deviation had not been made during the progress of the work; this being the [illegible] to be a man of large practical experience, as well as of sound theoretical knowledge, so that both constructor and manufacturer may be able to rely upon the soundness of his judgment. Unfortunately it is no uncommon experience in steel work to have an inspector reject in one case material which, though not quite complying with the letter of the specifications, is quite serviceable and acceptable, and in another case accept work and material which, though apparently in accordance with specifications, is unfit for use, and would be promptly rejected by the maker himself if he had an opportunity to decide.

In steel construction, probably more than in any other, the inspector is a necessary adjunct to the constructor; but ripe judgment, that familiarity with the material which can only be acquired in the mill and shop, and a thorough knowledge of the wants of the structure, coupled with the faculty of utilizing to the fullest extent the given means of the mill or shop, are absolute requisites for his usefulness. The sending of inspectors to steel works for educational purposes will be found fully as expensive to their employers as it is likely to be annoying and productive of loss to the steel maker, though it does occasionally afford some quiet amusement to superintendents and foremen.

The working of steel in every stage requires care, and, above all, intelligence, and the men engaged in it must be impressed with the necessity for careful manipulation and rational treatment.

PULLMAN SEWERAGE.

At the meeting of the Western Society of Engineers on Tuesday, a paper was read by Benezette Williams, late city engineer, and now in charge of the engineering work of Pullman, on "The Pullman Sewerage." The question of the disposal of the sewage of the new model town was a perplexing one, and Mr. Williams was authorized to make such investigations as might be necessary to devise a plan which should be in keeping with the other ambitions of the town. In view of the fact that the system finally adopted, and now in successful operation, possesses many new features, the substance of Mr. Williams' paper, describing it in detail, is given below. The paper is introduced by a description of the town, and a brief discussion of the merits of separate and combined systems of sewerage; that is, for rain or surface water, and sewage proper. It then proceeds as follows:

Pullman is a place for which the separate system is particularly well adapted, and for the following reasons: The site of the town is almost level, much of it not more than 7 or 8 ft. above Lake Calumet, making it impossible to obtain a gravity discharge to any other body of water than Lake Calumet. This lake is shallow—ranging from 1 to 8 ft. in depth. It is about 3 miles long and $1\frac{1}{2}$ miles wide. It drains a small area, and is connected with Lake Michigan by the Calumet River. The river, however, which drains a much larger area than the lake, does not run through the lake, but is connected therewith by a small channel, through which the water flows from the lake to the river, or from the river to the lake, according to the varying conditions of winds and floods. In the absence of any adequate means of purifying itself, Lake Calumet is wholly unfit for a receptacle of sewage. The small elevation of Pullman and the great distance to Lake Michigan render a gravity discharge thereto impossible. When a town cannot get rid of its sewage by a gravity discharge, the alternative is to use a pump. When a pump has to be relied upon, the exclusion of rain water from the sewers becomes almost a necessity, and when, as in this case, the surface-water can readily be carried off by a system of drains made for that purpose only, it adds strength to the reasons for fixing upon the separate system, which in this case was adopted for the reasons given, independently of its supposed sanitary merits.

The question of disposal, however, was not one that could be settled by the force of conditions. In selecting the place for and deciding upon the manner of disposal, there was room for a greater range of opinion and judgment, though, even in this the question was soon narrowed down to two parts. Lake Michigan could be reached with a pipe $6\frac{1}{2}$ miles long, and, by pumping, the sewage could readily have been discharged therein. The only alternative was land purification in some shape.

It was found that suitable land could be had three miles away, the title to which had been acquired by the Pullman Land Association. Estimates showed that a pipe could be laid to this land, a farm sufficient to dispose of the sewage of ten thousand people prepared, and suitable farm buildings erected for a less outlay than would be incurred in laying a pipe to Lake Michigan. It was believed that the farm could be made to pay expenses and the interest upon the money actually expended upon the farm proper, which would make the scheme of land purification considerably cheaper than the lake disposal, to say nothing of the objection felt to further contamination of a body of water that is already overcharged with filth. The plan of sewerage was determined upon, and the laying of the sewers begun, in August 1880, soon after the writer was employed as engineer of the water and sewerage works for Pullman. Six months later, in February, 1881, the method of disposal was decided by the adoption of the sewage farm projects. October 18, 1881, the system was put into operation on starting the sewage pumps.

The system of sewerage is designed to reach a tract of land two miles long and an average of something more than a mile wide, comprising about fifteen hundred acres of land. To drain this district three mains have been provided, which center at the water tower. The mains leading from the north and from the west are 18 in. in diameter, and the one leading from the south is 15 in. in diameter. These mains are laid with a grade of 1 ft. in 1000 ft. The 9-in laterals are laid with grades varying from 3 to 4 ft. per 1000 ft., and the 6-in. laterals with grades of from 4 ft. to 6 ft. per 1000 ft., according to circumstances, the maximum grade in each case being the one size in all but special cases. At their starting point, the mains are about 10 ft. below the general grade of the town, the extreme ends of the 6-in. sewers in the alleys being about 7 ft. below the yards in the rear of the houses. The ground in which the sewers are laid is a hard, tough, drift clay. Man holes are 180 feet apart on the mains and generally 2 300 ft. apart on the laterals, being built also at every change of grade and direction. They are covered with a ventilating iron cover, with a trough or channel under the openings to catch dirt.

In all there has been laid at Pullman up to June 1, 1882, the following amounts of sewers of the various sizes, exclusive of house connections:

4,356	lineal feet of	18-in.	sewers.
2,176	" "	15-in.	"
680	" "	12-in.	"
3,600	" "	9-in.	"
12,600	" "	6-in.	"
500	" "	4-in.	"

26,312 lineal feet in all.

In all cases outside of houses—in mains, laterals, and house-drains—salt-glazed, vitrified clay pipes of the Akron make have been used. Within the houses, soil-pipes are of iron, and were put in by the Durham House-Drainage Company, of Chicago. The vertical soil-pipes are wrought iron, coated with coal-tar, varnished, put together with screw joints, and the horizontal pipes are cast iron, with lead joints. The vertical pipes are 3 in. in diameter, and the horizontal pipes 4 in. in diameter. The horizontal pipe connects with the outside sewer without a trap. The vertical pipe runs through the roof, in all cases, full size. In most cases each soil-pipe has two or more water-closets connected with it. A pipe placed in a partition between two houses generally takes the soil for both houses. In cases of three-story flats, one pipe frequently has six water-closets connected. By these departures from the usual size of pipe and the usual manner of setting closets, a great saving in cost has been effected without inconvenience of any kind.

There have been—out of several hundred 3-in. soil-pipes that have been in use from two to eight months—perhaps six or eight cases of stoppage. But in every instance the stoppage was due to obstructions that got in during construction, and never to the use of a small-sized pipe. The results would unquestionably have been the same had 4-in. pipes been in use.

The sewerage system drains into a sewerage reservoir in the base of the water tower, the whole middle of the foundation of the tower having been excavated to a depth of thirty feet and all the space up to the grade of the sewers, not occupied by the walls, being used for storage. This holds about 300,000 gallons. Increased storage capacity can be had when needed by excavating a side chamber. It is expected that the present capacity will suffice for 8,000 population. Ventilation of the sewage reservoir is secured by means of eight flues lined with 12-in. sewer-pipe, built in the buttresses of the tower and opening at a height of 165 ft., and, also by a 30-in. pipe leading to the large chimney of the car-shops. The ventilation thus secured is perfect. The reservoir is arched over with groined arches, forming a floor for the sewage and water pumps, 10 ft. below the surface of the ground. The sewage pumping engines are direct-acting, compound-condensing, with piston pumps, each having a capacity of 2,300,000 gallons in twenty four hours. They were made with the special object of getting machines which would pump everything to be found in sewage, either of an ordinary or an extraordinary character. It was considered desirable to avoid screening or settling the sewage at the reservoir. All the sediment which collects in the reservoirs by incidental settling is from time to time washed loose with a hose and passed off with the liquid sewage. In order to accom- [illegible]

valves now, it will be sufficient to say that thus far they are working to great satisfaction. Cotton waste, large cloths, sticks and blocks of wood have passed through the pumps frequently; indeed, many such substances are daily passing without injury or inconvenience. Barring the riveting of two parts of the rubber together, where they were at first imperfectly joined, no repairs have been needed, and there is nothing to indicate aught but a long life for the valves. The pumps were made by the Cope & Maxwell Manufacturing Company, of Hamilton, O.

The sewage is conveyed to the farm by a 20-in. cast-iron main, nearly three miles long. The farm end of this main connects with a closed, screening-tank, by means of which all material that will not pass through a screen of ½-in. mesh is intercepted. The tank is 6 ft. in diameter and 24 ft. long, made of ¼-in. boiler iron. It is set vertically, with its lower end high enough above the floor to admit of a wagon being driven under it. The material intercepted by the screen is lodged in the lower part of the tank, from which it is removed from time to time. On leaving the tank, the sewage passes through a pressure-regulating valve, which limits the pressure that comes upon the pipes leading to the fields to about ten pounds. As an additional precaution against high pressure, an overflow-pipe is provided, which will absolutely, under all conditions, prevent the pressure from rising above the limit. This pipe comes into play occasionally when the pumps are started suddenly without giving the valve time to act. The valve is purposely made to act slowly, in order to avoid the influence of pulsations in the engines and irregularities from other causes. A pressure on the interior of the thin steel disks above the valve raises the plunger, and closes the ports through which the sewage passes. If the pressure falls the ports open gently. Vibrations of the valve from sudden changes of pressure are prevented by a plate between the valve and the steel disks, through small holes in which the sewage has to pass in order to increase or diminish the pressure on the disks. The upper part of the tank, above the screen, is an air chamber, and answers the usual purpose of such an adjunct in preventing shocks from irregularities in the pumps, or by the sudden stopping of the flow of sewage. The tank and valve are housed in, and can be kept warm to prevent freezing in cold weather. The reason for introducing the pressure-regulating valve between the screening tank and the field is to make it possible to distribute sewage safely through clay sewer-pipes under pressure.

The main distributing pipe is 18 in. in diameter. From this main four lines of 9-in. pipe, 316 ft. apart, are laid across the field. Every 330 ft., on each line of 9-in. pipe, a hydrant is set, thus giving one hydrant to each 2½ acres, or thereabouts. On an 80-acre tract, which is now being underdrained, it is probable that two lines of 12-in. pipes will be used to distribute the sewage. This tract lies more favorably for surface distribution than the one prepared last year, and it is believed that fewer lines of pipes and hydrants will be sufficient. The pipes laid last year for distributing the sewage were of Akron make, with socket joints. The first pipes ordered were made with 3-in. sockets, but it was afterward found that sockets of ordinary depth would make a tight joint.

Before laying the pipes it was thought best to make a test as to whether weak or cracked pipe could be detected by ordinary inspection. An application of hydraulic pressure developed the fact that no inspection possible to apply could be relied upon. Many pipes that looked rough and full of fine cracks, that would ordinarily be rejected, were found to be among the best. While, on the other hand, the clearest ringing and best appearing pipes were often the poorest. These results made it necessary to apply the test generally. The test applied was 20 lbs. pressure per square inch. It was soon found that this pressure would break too large a proportion—about two-fifths of the 18-in. pipe, so it was decided to lay the main in concrete without testing. The 9-in. pipes stood the test better, about one pipe in four being broken in the operation. This loss could be stood and still the sewer pipe be much the cheapest thing that could be used for the purpose. It was a noticeable peculiarity of the pipes that 75 per cent. of those that failed broke below 10 lbs. The bed of concrete around the 18-in. main was from from 4 to 6 in. in thickness. The bottom was generally made of the Utica cement mortar and broken stone, while for the top and sides Portland cement was used. The 9-in. pipes were laid with stiff Portland cement mortar mixed with an equal quantity of sand. A hemp gasket was tried at first, but it was soon found that the quickest and best way in every respect to make a joint was to make a bed of mortar on the lower half of the socket and insert the next pipe; then, with the trowel, to force the mortar into the annular space on the top until the mortar was forced through into [illegible]

fective joints, and this was caused by a heavy rain during the pipe-laying.

The general conclusion from this experience in the use of clay sewer pipes to carry fluids under pressure is that for light pressure from 10 to 15 lbs. the smaller-sized pipes are well adapted to the purpose if proper care is used in selecting them and in securing the joints as they are laid. I consider it by no means certain that sizes up to 18 in. cannot be profitably used, as I do not think that the lot of pipe of this size that we had was of the best quality. Thin pipes seemed to give better results than thick ones.

The system of underdrainage on 60 acres prepared last year consists of one main underdrain, from 6 in. to 12 in, in diameter, of sewer pipe, laid north and south, and emptying into a ditch that discharges into Lake Calumet, and of parallel lines of common tile, 2 to 4 in. in diameter, laid at an average depth of 3½ ft., and an average distance of 40 ft. apart. The tile were laid with strips of tarred paper tied around the joints. Ten ft. of tile were strung on a pole at the side of the trench, the joints wrapped, and the whole 10 ft. put in place at one operation.

As to any of the general results of sewage farming, it is too soon to speak from experience upon the Pullman farm. The ground was covered with a tough sod, much of it a coarse, wild grass, and was plowed late last fall. The sod is still so tough that it is impossible to put it in proper shape for irrigating the crops. Then the spring has been so backward, owing to wet and cold, that no kind of crops are much advanced in this region. Difficulty is also being experienced by the grass starting to grow upon the land where sewage has been applied during May. It is intended to underdrain, a rod apart, a portion of land best adapted to sewage purification for filter beds, to be used as a safety valve, when if applied to ordinary crops the sewage would be an incumbrance. Upon these filter beds some of the coarser kinds of crops can be grown. As soon as the farm has really been fairly started, which, owing to the reasons given, cannot be before next year, I see no cause to doubt the success of the enterprise.

There is one feature of the system of direct pumping of the sewage at Pullman which may be of interest. The pumps, screening tank and pressure-regulating valve are so arranged and are so dependent one upon another that notwithstanding the use of clay pipes for distributing the sewage the workmen on the farm can control the quantity of sewage received with perfect safety. They close and open hydrants to any desired extent and vary the amount of sewage discharged almost as they please without danger or inconvenience. The operation is this: If the sewer is flowing at any given rate and one or more outlets be closed the effect is partially to close the pressure-regulating valve, by a slightly increased pressure on the distributing pipes, and to transmit from the valve, through the force main, an increased pressure to the pumps, which are provided with a steam regulator that reduces the pressure of steam admitted to the cylinders. In order to avoid all possibility of injury to pipes or pumps in this operation, a stand-pipe with two overflows is provided at the pumps, as well as one at the regulating valve, so that there is an absolute guarantee against damage from the failure of any mechanical appliance. The stand-pipe connected with the pump-main in the tower is, measuring from datum, 54 ft. high to the first overflow, and 90 ft. high to the second overflow. These overflows are connected with a pipe which returns the sewage to the reservoir below the pumps, so that, if every outlet is closed at the farm, the pumps could continue to run with freedom. Should the pressure-regulating valve fail to perform its functions, the overflow pipe then will protect the clay distributing pipes from undue pressure.—*Chicago Times, June 9.*

NOTES.

The Railroad Builders.

The most important to us of all the railroad building now in progress is that in Mexico, which will soon bring us into commercial relations with her nine millions of people.

The Sinaloa & Durango Railway, which is to connect the Pacific port of Altata in the State of Sinaola with the city of Durango on the main line of the Mexican Central, will be completed to Culiacan about July 1. The grading is already finished to that point.

The road from Merida to Valladolid is advancing rapidly. This appears to be a recent project. It is not denoted on the maps which we have seen. Yucatan is a very promising State, lying directly south of the jetties.

The *Rio Grande Valley*, a paper published at Brownsville, Texas, says that the Matamoros road is now completed nine miles. This is one of the spurs of the Mexican National, and runs up the river to Mier, whence it strikes southwest into the [illegible]

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this great decrease in volume must in part be compensated by the use of extra pumping equipment and external cooling apparatus whereby a high circulation of cool acid may be maintained. Furthermore, the present nitric oxide-water absorption tower systems require a larger installation to obtain a 90 per cent absorption efficiency than those Gay-Lussac tower sets which operate on about 85 per cent efficiency. Our estimates indicate that this process is worthy of study on a larger scale.

Bibliography

1—Wells and Fogg, Bur. Mines, *Bull.* 184.
2—Miller, *Chem. Met. Eng.*, 22, 1155 (1920); U. S. Patent 1,225,348.
3—Thede, *Z. angew. Chem.*, 26, 1 (1913).
4—Lunge, "Sulfuric Acid and Alkali," Vol. I, Pt. 2, p. 686 (1913).
5—Gilchrist, *J. Soc. Chem. Ind.*, 13, 1162 (1894).
6—Pratt, *Am. Fertilizer*, 13, 23 (1900); U. S. Patents 546,396 and 652,687.
7—Chemical Construction Company. Bulletins.
8—Falding and Cathcart, J. Ind. Eng. Chem., 5, 223 (1913); U. S. Patent 932,771.
9—Lunge, *Op. cit.*, 3rd ed., p. 450.
10—Meyer, *Chem.-Ztg.*, 34, 981 (1909).
11—Thiele, *Trans. Am. Inst. Chem. Eng.*, 12, 171 (1919).
12—Kaltenbach, *Chimie et industrie*, 3, 487 (1920).
13—Fairlie, *Chem. Met. Eng.*, 24, 795 (1921).
14—Gaillard, British Patent 202,830 (1922).
15—LeBreton, *Chimie et industrie*, 11, 663 (1924).
16—Fairlie, *Chem. Met. Eng.*, 25, 1005 (1921).
17—Larison, *Ibid.*, 22, 1127, 1174 (1920); 26, 800 (1922).
18—Larison, U. S. Patents 1,342,934 and 1,394,364 (1920).
19—Wilke, *Chem. Trade J.*, 51, 394 (1912).
20—Opl, U. S. Patent 1,012,421 (1911).
21—Hartmann, *Z. angew. Chem.*, 24, 2002 (1911).
22—Meyer, *Z. angew. Chem.*, 26, 208 (1913).
23—Schmiedel, British Patents 140,647, 140,648, and 164,906 (1921).
24—Schmiedel and Klencke, British Patent 157,916 (1921).
25—Parrish, *Chem. Age*, 20, 316 (1924); 26, 130 (1926).
26—Peterson, *Chem.-Ztg.*, 35, 698 (1911).
27—Peterson, *Ibid.*, 47, 227 (1923).
28—Tungay, *Ibid.*, 6, 381 (1922).
29—Quinan, *Chem. Met. Eng.*, 22, 347 (1920); U. S. Patent 1,334,357.
30—MacNab, *Chem. Age*, 6, 373 (1922).
31—Chem. Fabrik Griesheim Elektron, French Patent 408,841 (1909).
32—Ason, *Ind. Chim.*, 11, 127 (1911); *cf. Chem. Abs.*, 5, 2001 (1911).
33—Fairlie, U. S. Patent 1,420,477 (1922).
34—Partington and Parker, *J. Soc. Chem. Ind.*, 38, 75 (1919).
35—Burdick and Freed, *J. Am. Chem. Soc.*, 43, 518 (1921).

Disposal of Industrial Wastes[1]

Wastes from Corn Products and Paint and Dye Works

F. W. Mohlman and A. J. Beck

Sanitary District of Chicago, 1014 South Michigan Ave., Chicago, Ill.

THE industrial waste problem is of particular importance in Chicago from several standpoints. There are various classes of wastes, some of which augment the sewage load, others interfere with sewage-treatment processes, and others from nearby cities cause tastes in the water supply. Detailed investigations have been made of three types of wastes in the first classification—namely, those from stockyards and packingtown, from tanneries, and from a corn products refining company. Extensive studies have been made of the second type—namely, wastes from a paint and dye factory, which have seriously interfered with the operation of a sewage treatment plant. Studies are now being made of the third type, wastes from by-product coke plants, particularly with the object of determining whether it is feasible to handle such wastes, mixed with sewage, in a sewage treatment plant.

This paper will deal exclusively with the results of investigations of corn products wastes and paint and dye wastes. It is intended to show that the problem of disposal of wastes frequently becomes simplified if a thorough study is made of the various types of wastes contributing to the problem, followed by intensive study in the factory of methods for eliminating or minimizing wastes from certain processes in order of their importance. In the case of the Corn Products Refining Company, the outcome was far more gratifying than had been anticipated when the studies were commenced, and what at one time appeared to be a costly process of sewage treatment was changed to a scheme of recovery of valuable corn solids worth possibly half a million dollars per year.

Our studies of the industrial waste problem in general have indicated that industrial chemists do not always appreciate the problem from the same angle as chemists and engineers who are interested in sewage treatment and prevention of stream pollution. The sanitary chemists and engineers deal with sewages which contain only 0.01 or 0.02 per cent of suspended solids and rarely more than 0.1 per cent of total solids. They are interested primarily in oxygen demand of wastes, whether they are inhibitive to bacterial action, or whether they may interfere in one way or another with biological processes of sewage treatment. The industrial chemist is usually concerned with concentrations far greater than the parts per million of the sanitary chemist; he rarely has studied the biochemical oxygen demand, pH, bacterial content, or toxic effect of waste discharged from his factory. When coöperative investigations are made, such as have been conducted in two instances described in this paper, a better understanding is gained of the viewpoint from both sides.

CORN PRODUCTS WASTES

The wastes from the Corn Products plant at Argo have been studied since 1920. A testing station was operated for six years,[2] and after it had been discontinued daily analyses were made of all wastes of importance discharged from the plant.

Source and Nature of Wastes

The corn received at the plant is first steeped in a weak solution of sulfur dioxide.[3] This process softens and swells the kernels so that the separation into various products may be accomplished. The steeping is on the countercurrent principle and the sulfur dioxide water is kept in circulation until the total solids build up to a concentration of about 7 per cent. The "light steepwater" is then drawn off and concentrated to 45 per cent solids in vacuum evaporators. The sirupy "heavy steepwater" is added to other parts of the corn to produce a valuable stock food which sells for $30 or $40 per ton. This process of recovery is important, since it was the main factor in solving the problem of disposal of wastes from this factory.

[1] Presented before the Division of Water, Sewage and Sanitation at the 76th Meeting of the American Chemical Society, Swampscott, Mass., September 10 to 14, 1928.

[2] Mohlman, Ind. Eng. Chem., 20, 1076 (1928).

[3] Sjostrom, Ibid., 8, 300 (1916).

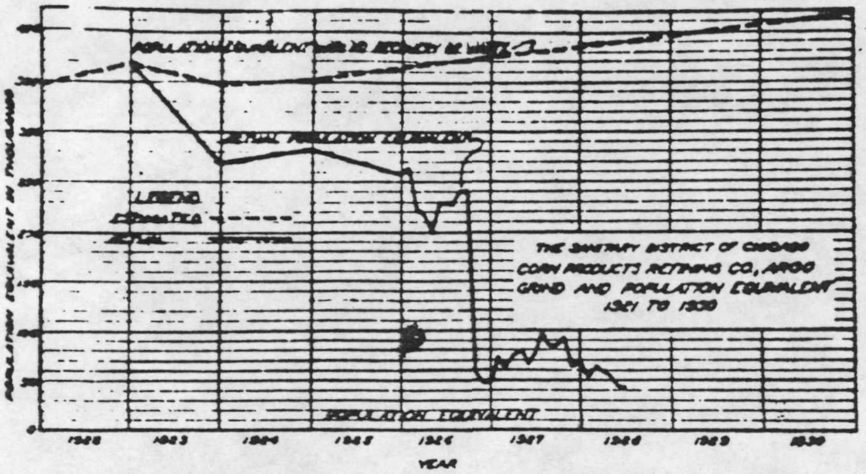

Figure 1—Reduction of Population Equivalent of Wastes from Corn Products Refining Company

(so-called "bottling-up") and evaporation. This process appeared simple, but in reality it introduced many difficulties which had to be solved before it was finally adopted. There was also considerable expense for new equipment, but the hope of recovery of 2 per cent of the corn warranted this expense. In September, 1926, the "bottling-up" process was put into effect. The results speak for themselves as shown in Figure 1.

Reduction of Organic Content of Wastes

If no recoveries had been effected, the population equivalent would now be nearly 400,000. As a matter of fact it is approximately 50,000.

Our studies have been devoted to methods for reduction of this equivalent ever since the "bottling-up" process was effected. Comparing the results in 1924 and the first six months of 1928, the reduction was as follows:

	Per cent
Reduction based on total solids	[illegible]
Reduction based on organic nitrogen	[illegible]
Reduction based on biochemical oxygen demand	81

The disposal or treatment of the residual wastes resolved itself into a study of two major wastes. First in importance is the condensate from the steepwater evaporators, and next the refinery wash water used for washing bone carbon after it has been tempered. The importance of these two wastes compared with the total plant wastes is shown in Table II. Considerable time has been devoted to a study of what could be done with these wastes.

After the steeping process gluten and starch are separated and removed. Some starch is converted into glucose and many varieties of products are made from the three basic products—namely, starch, gluten, and feed.

The relative importance of the individual wastes in 1924 is shown in Table I, which indicates that the starch and gluten overflow comprised nearly 90 per cent of the total loss of solid matter, amounting to approximately 2.2 per cent of the weight of dry corn ground.

Table I—Distribution of Losses of Solids. Corn Products Refining Company, 1924

	Solids Lost per 24 Hours	Total Losses	Dry Substance Ground
	Pounds	*Per cent*	*Per cent*
Gluten overflow	58,400	77.8	1.92
Starch overflow	7,900	10.9	0.25
Refinery wash water	5,430	7.2	0.18
Steepwater vapors	3,070	4.1	0.10

The population equivalent of the wastes, based on oxygen demand determinations, is shown in Figure 1 for all years from 1922 to date. It is an interesting story to follow the history of the successive reduction in total oxygen demand of the wastes, but only the high spots can be mentioned here. When the testing station was started in operation, analyses of samples from the sewer revealed many losses, the importance of which was not appreciated up to that time by the Corn Products Company. These losses of organic solids occurred irregularly in so-called "shots," and each of these "shots" would upset the operation of the biological processes of sewage treatment. It was found by more careful operation of settling processes in the factory, and by collection of samples with an automatic sampler, that many of these losses could be prevented. Through 1925 all efforts were centered on the prevention of losses of insoluble solids. The curve indicates that not much more benefit could be expected along this line. About this time the results of operation of the testing station indicated that a sewage treatment plant consisting of 25 acres of trickling filters would be necessary for treatment of the wastes, at an estimated cost of construction of $2,900,000. This tremendous expenditure stimulated intensive study to determine whether the soluble solids could be recovered. Edward Bartow, who was retained by the Corn Products Company as consulting chemist, aided materially in the preliminary work. After thorough study by the company, it was decided that it might be possible to recover most of the solubles by a process of recirculation

Table II—Population Equivalents of Residual Wastes. Corn Products Losses

Month 1927–1928	Population Equivalent: Steepwater losses	Population Equivalent: Refinery wash-water losses	Population Equivalent: Other losses (by diff.)	Population Equivalent: Total	Per Cent of Total: Steepwater losses	Per Cent of Total: Refinery wash water	Per Cent of Total: Other losses
Dec.	38,300	16,800	13,300	68,300	55.5	24.4	20.1
Jan.	45,000	14,300	14,800	74,000	60.5	19.3	20.0
Feb.	33,000	14,400	17,600	65,000	50.7	22.3	27.1
March	43,800	13,380	2,800	59,800	73.3	20.4	6.3

Steepwater Vapors

The steepwater is evaporated in single- and triple-effect pans with vacuum produced by barometric condensers. Approximately 10 million gallons of canal water a day are used for producing the vacuum, and the vapors and entrainment losses are condensed and diluted in this large volume of water. In the triple-effect system the concentrated, condensed vapor collects in the second and third pans. The condensate is quite hot, acid, and sterile. It would be expensive to treat the large volume of waste from the single-effects, since several acres of trickling filters would be necessary. The 10 million gallons of waste have an oxygen demand (20-day) of approximately 140 p. p. m.; consequently it should be treated in some way. A study has been made of the concentrated liquor from the triple-effect pans to indicate the source of this oxygen demand.

Results of such studies are shown in Table III. In the first series it is noted that there were entrainment losses of non-volatile solids which greatly increased the oxygen

V2

Table III—Biochemical Oxygen Demands and Analyses of Condensed Steepwater Vapors Collected from First and Second Effects of Triple-Effect Pans

Sample	5-Day Biochemical Oxygen Demand: Original sample	Acids	Alcohols and neutral compds.	Bases	Residue	Organic Nitrogen (+ Ammonia)	Iron	Esters as Ethyl Acetate
	P. p. m.	P. p. m.	P. p. m.	P. p. m.	P. p. m.	P. p. m.	P. p. m.	P. p. m.
First series:								
1st effect	[illegible]	1630	[illegible]	10	3900	311	180	15.4
2nd effect	3360	3000	1600	13	30	6.1	130	11.0
Second series:								
1st effect	1000	470	300	10	30	7.1	180	12.3
2nd effect	1000	330	400	14	25	6.8	120	6.8

demand of the condensate. In the second series it is apparent that there were practically no entrainment losses; therefore the oxygen demand is due entirely to vapor losses. It will be noted that acids and alcohols are mainly responsible for the oxygen demand. The acids and alcohols have been separated and identified. The results are too detailed to be included, but in brief, propionic acid makes up more than one-half of the volatile acids, about one-third is acetic acid, and the rest is butyric and valeric acids. Of the alcohols, ethyl alcohol makes up 85 to 90 per cent of the total, with the remainder propyl and higher homologs.

A further study is required along these lines to determine whether there is any value in the recovery of these substances from the condensed vapors, amounting to 400,000 gallons per day. A laboratory study has been made of the percentage of oxygen demand of the substances distilling over in the "batch" process of distillation. In this procedure 600 cc. of steepwater were distilled in the laboratory under vacuum and 60 cc. fractions collected, on each of which the oxygen demand was determined. The results are shown in Table IV and Figure 2. It is quite interesting to note that 80 per cent of the oxygen demand substances distilled over in the first 15 per cent of the distillate. If it were possible to strip off a small portion of the condensed liquors in this way, the population equivalent of steepwater vapor losses could be reduced by about 32,000, which would probably obviate the necessity for biological treatment of the remaining vapors.

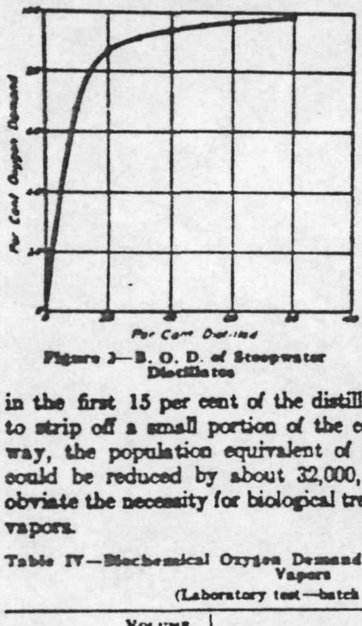

Figure 2—B. O. D. of Steepwater Distillates

Table IV—Biochemical Oxygen Demand of Condensed Steepwater Vapors
(Laboratory test—batch method)

Fraction	Volume of Fraction	B. O. D. of Fraction		B. O. D. in Fraction	Cumulative B. O. D.
	Cc.	P. p. m.	Mg. O_2	Per cent	Per cent
1	60	37,800	2270	67.8	67.8
2	60	10,800	648	19.3	87.1
3	60	2960	177	5.3	92.3
4	60	1130	68	2.0	94.3
5	60	730	43	1.3	95.6
6	60	557	33	1.0	96.6
7	60	430	26	0.7	97.3
8	60	560	34	1.0	98.3
9	60	970	58	1.7	100.0
Composite	540	6200	3357		

The analyses of steepwater vapors shown in Table III indicate that very little nitrogen is present. The rate of oxygen demand shown in Figure 3 is typical of carbohydrate wastes, as found previously by one of the writers.[4] There is no appreciable secondary stage and very little increase after the fifth day.

[4] Mohlman, Edwards, and Swope, Ind. Eng. Chem., 20, 242 (1928).

Refinery Wash-Water Losses

Refinery wash-water losses amount to approximately 350,000 gallons per day, with a 5-day B. O. D. of about 700 p. p. m. The pH is approximately 5.8, and 6.2 when diluted with an equal volume of water from the drainage canal. Studies of aeration of this waste and treatment by the activated sludge process gave very unsuccessful results. The waste was too hot and too acid, and even when diluted with canal water it was impossible to produce a satisfactory activated sludge. For several years a small trickling filter has been dosed with this waste. The results indicate that it is not possible to handle this liquor successfully when undiluted, but when diluted with an equal volume of canal water quite successful results have been obtained at a rate of 1.5 m. g. d. (million gallons per day) per acre. The oxygen demand was reduced more than 90 per cent; consequently the population equivalent of this waste can be reduced about 13,000.

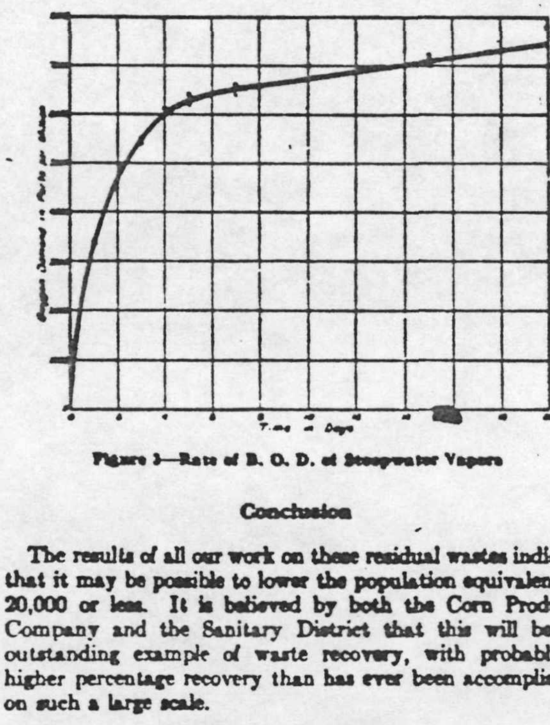

Figure 3—Rate of B. O. D. of Steepwater Vapors

Conclusion

The results of all our work on these residual wastes indicate that it may be possible to lower the population equivalent to 20,000 or less. It is believed by both the Corn Products Company and the Sanitary District that this will be an outstanding example of waste recovery, with probably a higher percentage recovery than has ever been accomplished on such a large scale.

PAINT AND DYE WASTES

Extensive studies have been made of the effect of toxic acid and metal-containing wastes on the operation of the Calumet Sewage Treatment Works. A program of detailed study of individual wastes has lead to the adoption of methods for elimination or neutralization of the objectionable constituents.

The Calumet Treatment Works of the Sanitary District of Chicago has been in operation since 1923. It includes thirty Imhoff tanks used for sedimentation and two remodeled tanks used for activated sludge treatment. There is also a trickling filter 0.75 acre in area.

Introduction of Paint and Dye Wastes

Very successful results were obtained from the operation of the plant until the sewers from the Sherwin-Williams Paint Company were connected to the intercepting sewer feeding the treatment works, in November, 1924. In December a noticeable deterioration in the quality of the activated sludge and trickling filter effluents was noticed, and this became more serious in January, 1925, and succeeding months. Some results of analyses of trickling filter effluent and rates of filtration are plotted in Figure 4, before and after the introduction of the Sherwin-Williams wastes. There was

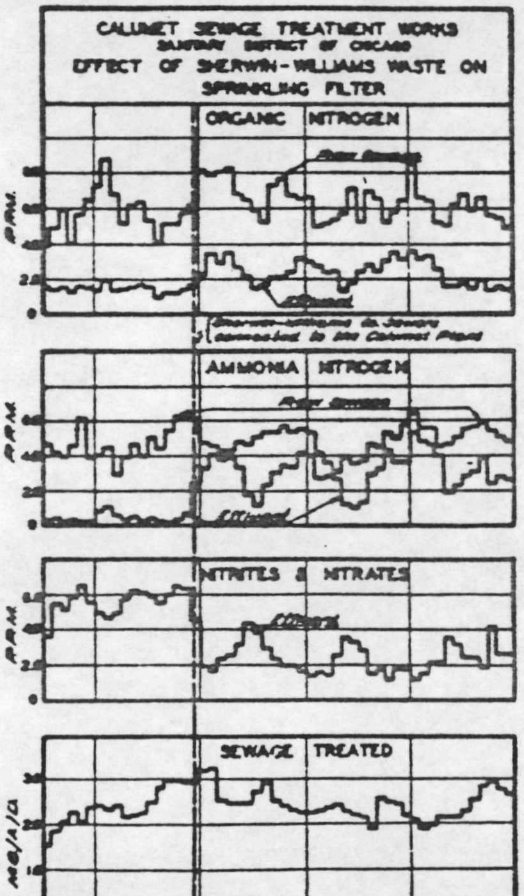

Figure 4—Effect of Sherman-Williams Wastes on Operation of Trickling Filter at Calumet Sewage Treatment Works

a decided increase in organic and ammonia nitrogen and decrease in nitrite and nitrate nitrogen following the introduction of the wastes.

The effect on the activated sludge process was even more noticeable. The amount of sewage treated in one of these tanks had to be decreased from 2.0 to 1.0 m. g. d., and the air increased from 0.67 to 2.00 cubic feet per gallon shortly after the wastes appeared.

The analyses showed that the effect of the wastes was to make the sewage considerably more acid, decrease the content of dissolved oxygen, increase the oxygen demand, and decrease the bacterial content in the raw sewage (although an increase in the effluents). Iodine titration indicated the presence of considerable sulfur dioxide. The Sherwin-Williams Company did not buy or use sulfites, but the source of the sulfur dioxide was later discovered in the sodium sulfite produced as a by-product from the sulfonation of naphthalene, in the manufacture of beta-naphthol.

Nature of Wastes

The great variety of products and processes in the factory made it necessary to investigate the source and character of all wastes. The information desired was obtained in some cases from the records of the company, but mostly from gagings and analyses of wastes as discharged. The most important wastes were found to he as follows:

(1) Sulfuric acid wastes from the manufacture of p-nitraniline are discharged intermittently. The total discharge averages 40,000 gallons per 24 hours, containing 16,000 pounds of sulfuric acid, approximately a 5 per cent solution.

(2) Wastes from the manufacture of Paris green contain copper and arsenic. This insecticide is manufactured only part of the year, usually in the winter and spring. When the plant is operating, the volume of waste is approximately 12,000 gallons per 24 hours, containing from 80 to 110 pounds of copper as Cu and 700 to 800 pounds of arsenic as As_2O_3.

(3) The source of sulfur dioxide is the waste liquors from the manufacture of beta-naphthol. In this process naphthalene is sulfonated with sulfuric acid and the sulfonation mixture is neutralized with sodium hydroxide. The filtrate containing sodium sulfite is discharged to the sewer, in volume about 8000 gallons per 24 hours, plus 2800 gallons of wash water. The combined wastes contain about 2700 pounds sodium sulfite per 24 hours.

(4) Other wastes are too numerous to describe, but are considered to be of lesser importance with regard to their effect on processes of sewage treatment. Highly-colored wastes are discharged from the manufacture of fuchsin; several hundred pounds of lead per day from the white-lead department; zinc, iron, and chromium from inorganic pigments; and large volumes of wash water from all departments.

The volume of wastes was measured in the two sewers which served the plant in June, 1926. The total volume was found to be 1.23 m. g. d.; the wastes were highly acid, and contained most, if not all, of the substances listed above. The total volume at times is 2.0 m. g. d. as compared with the following flows of sewage plus waste at the Calumet Treatment Works:

	M. g. d.
1925	34.8
1926	41.3
1927	41.6

Acid Wastes

Analyses of the sewage at the treatment works have always been made daily on a 24-hour composite. In view of the intermittent discharge of wastes from the Sherwin-Williams Works, two 24-hour tests were made in which samples were collected and analyzed every 10 minutes. Results of one of these tests are shown in Figure 5.

The acid liquors were discharged in six batches, each batch over a period of $1^1/_2$ hours. The time of flow to the treatment works varied, as shown, between 2 and $2^1/_2$ hours. The effect of the wastes on the pH, alkalinity, and bacterial content is shown in Figure 5. The pH frequently dropped to 5.0, with a minimum of 3.0; the alkalinity (to methyl orange) was frequently almost completely neutralized; and the bac-

Sulfite Wastes

The sulfite wastes are quite alkaline as discharged and when diluted in the sewer. The amount of sulfur dioxide present is sufficient to use up an appreciable amount of dissolved oxygen; consequently, it is considered desirable to remove the sulfite liquors from the sewer. They can probably be used for neutralization of acid sulfonation liquors, with liberation of sulfur dioxide, which can be absorbed in alkali, if necessary, or discharged through a high stack.

Other Wastes

It is probable that no treatment of the other wastes discharged from the plant will be necessary if the treatment program can be confined to the three wastes described above. With a total volume of only 60,000 gallons the cost will undoubtedly be much less than any attempts to handle the entire volume of wastes, amounting to 1.25 up to 2.00 million gallons per 24 hours.

Chemical Treatment of Trade Waste

V—Waste from Wool Washing[1]

Foster Dee Snell

130 Clinton St., Brooklyn, N. Y.

The process herein recommended is a combination of two well-known processes, acid-cracking of wool washings and aluminum sulfate coagulation. By combining the two processes, wool washings have been purified to give an effluent suitable for discharge into streams or for re-use.

In the process as outlined, coarse dirt is first settled in detritus chambers. By treatment with aluminum sulfate, fats, waxes, soaps, and fine dirt are removed as a sludge, which requires further treatment. Part of the nitrogenous materials are removed in this sludge and the remainder are left in solution. Substantially all of the potash remains in the solution, which is suitable for re-use in wool washing or for discharge into the river. This water is apparently clean. Aluminum sulfate is recovered for re-use. Degras is obtained. Nitrogenous fertilizer material may be a by-product. The cost of treatment is not greater than the value of the by-products recovered.

Wool washings constitute a highly polluting waste consisting of an emulsion of lanolin and a suspension of dirt and bacteria in water, with soap and complex proteins as emulsifying agents. Considerable amounts of dissolved organic nitrogenous compounds are present. Soda ash–red oil soap is commonly used in the process. The disposal of wool washings vies in complexity with that of tannery waste liquors, and the two have many points in common. Unlike tannery waste, wool washings contain materials of known value. The recovery of lanolin from this waste has been practiced for many years. Recovery of the nitrogenous fertilizing ingredients is practiced on a mixed waste in England.

Methods of analysis are those previously used in this laboratory,[2] color readings being those of the Lovibond tintometer for a 50.6-mm. layer.

The experimental work described herein includes a study of both acid-cracking and coagulation, for the purpose of obtaining a substantially clear and colorless effluent. The work was first carried out in the laboratory, then checked in a 1 per cent experimental plant.

Wash House Operation

In this plant wool is washed by a counter-flow system. In the morning the bowls are filled with fresh water containing soap and soda ash. As the day progresses, the wash water becomes more and more contaminated and from time to time soap–soda ash solution is added, thus causing an overflow of waste. The total day's discharge is 45,000 gallons, largely late in the day when the bowls are dumped. About 50,000 gallons of circulation water are available. Sanitary waste is handled by a separate system. Analysis of the waste shows a neutral fat content of 0.6 to 1.5 per cent, and fatty acid as soap, of 0.3 to 0.7 per cent. The average value is about 1.1 per cent neutral fat and 0.33 per cent soap. Table I shows data on the waste throughout a typical day.

Methods of Treatment

Processes in use or proposed follow:

Acid-Cracking—This is the simplest and most widely used method. The effluent is only partially purified.

Centrifuging for Lanolin—In this process the waste liquors are settled to remove grit, heated, and centrifuged. Lanolin is recovered and a partially purified liquor is discharged to the stream.

Solvent Extraction, Followed by Washing—This process is installed in two plants, but owing to the dead appearance of the wool, high cost of operation, and danger of fire, it has not been a success.[3]

Coagulation with a Metal Hydroxide—This process is old,[4] but is generally considered too expensive for use without by-product recovery.

Miscellaneous Methods—These include steeping for potash recovery followed by grease removal, treatment with flue gases, spray drying, aeration, chlorination,[5] and others.

Separation of Grit

The experimental plant was based on 1 per cent of the total day's discharge, or 450 gallons per day. Four detritus chambers of different dimensions but the same capacity, without baffles, were provided in order to determine whether a large, shallow chamber or a small, deep chamber would be most efficient for this waste. Each detritus chamber had a capacity of approximately 150 gallons to give a detention of about 3 hours. It was learned early in the operation of the plant that the shape of the detritus chambers made little

[1] Presented before the Division of Water, Sewage and Sanitation at the 76th Meeting of the American Chemical Society, Swampscott, Mass., September 10 to 14, 1928.

[2] *Am. Dyestuff Reptr.*, 16, 84 (1927).

[3] Veitch and Benedict, *Trans. Am. Inst. Chem. Eng.*, June, 1908; *Am. Dyestuff Reptr.*, 13, 449 (1924).

[4] Turner, U. S. Patent 743,908 (1903).

[5] de Reeve, U. S. Patent 1,343,334 (1920); Ind. Eng. Chem., 17, 827 (1925).

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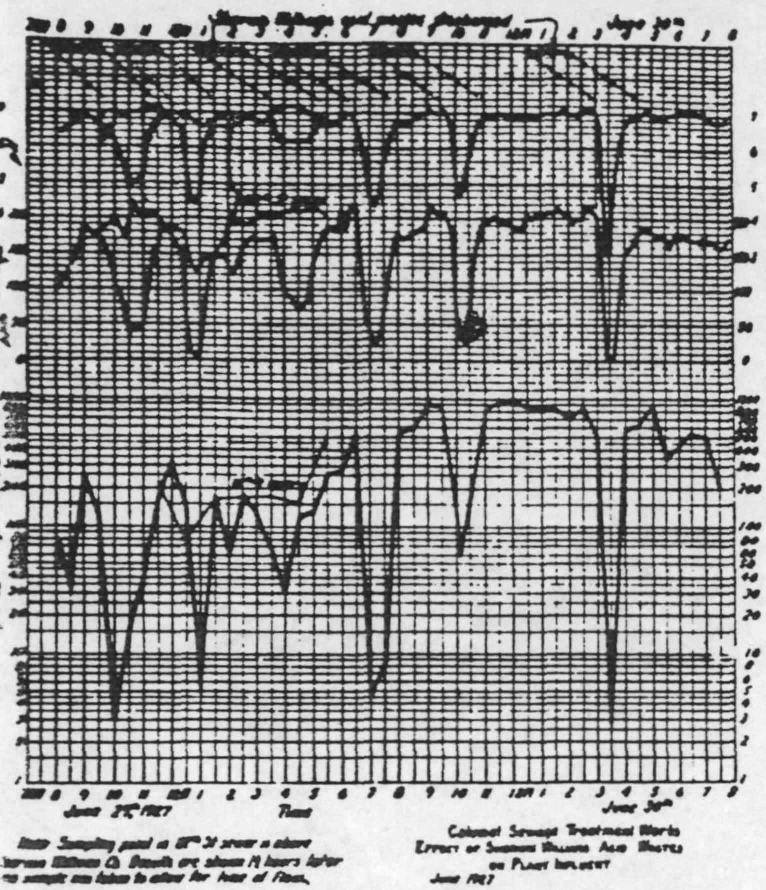

Figure 5—Analyses of Samples of Sewage Collected at 10-Minute Intervals

...ial count dropped at times to less than 5000 per cubic ...ntimeter.

Routine determinations of pH have been made daily on ...ven samples of the raw sewage at the treatment works. ...e results of such analyses are plotted in Figure 6, in which ... maximum, minimum, and average pH results are shown ...fore, during, and after a period when the p-nitraniline ...ant was shut down. The extremes may have been greater ...an indicated, since there was a lapse of 4 hours between ...alyses (with one special sample at a 2-hour interval).

Various proposals for elimination of this acid waste have ...en considered. Recovery of the sulfuric acid by concen...ation of the 5 per cent solution would be quite expensive. ...eutralization by means of lime (90 per cent CaO) would ...quire 5 tons per day, with production of 11 tons of dry ...lcium sulfate, or 28 tons of press cake at 60 per cent mois...re. The use of lime, filter-pressing, and disposal of this ...rge volume of sludge would be very expensive. It would be ...eaper to use limestone for neutralization instead of lime, ...nd some experimental work using limestone has been done. ...t was found that the native limestone could be used, but ...t would either have to be ground to 100 mesh or used in the ...ump form in a revolving drum, in order to get a reasonable ...ate of neutralization.

After consideration of the magnitude of any neutralization process and the expense involved, it was decided that the first step toward elimination should be to try the effect of equalization of acid discharge by installation of a balancing tank at the paint works. This tank, with a capacity of 18,000 gallons, has been installed, and will be ready for operation in the near future. It is estimated that the average pH may be brought up to 6.4 or higher. Although this reaction is still too acid for optimum conditions of bacterial action in a trickling filter or the activated sludge process, it may be possible to operate without further neutralization.

The 8 tons of sulfuric acid increase the SO_4 content of the sewage by approximately 45 p. p. m., but there has apparently been no difficulty because of increased production of hydrogen sulfide.

If the problem of disposal of this acid waste can be solved in this way, it will be far cheaper than any process of neutralization with lime or limestone. It is hoped that even partial neutralization may not be necessary.

Paris Green Wastes

Studies have been made of the possibility of precipitating copper and arsenic from the Paris green waste liquors by means of lime. It was found that approximately 1 ton of lime would be required per day to precipitate both the copper and arsenic, but about one-fourth this amount would be sufficient for the copper alone. After consideration that the amount of As_2O_3 added to the sewage would be only about 1.0 p. p. m., it was concluded that the removal of arsenic might not be necessary, since previous investigations, particularly in Massachusetts, have indicated that arsenic is not very inhibitive to biological processes of sewage treatment.

It is concluded that the copper must be removed, even though averaging less than 1.0 p. p. m. in the sewage. Studies at New Haven, Conn., have indicated that even small amounts may interfere with nitrification.

Instead of using lime for removal of copper, it is probable that iron filings will be used, similar to the "cementing" process for removal of copper from smelter tailings. This process would recover the copper in the metallic form. A plant will soon be installed for this purpose.

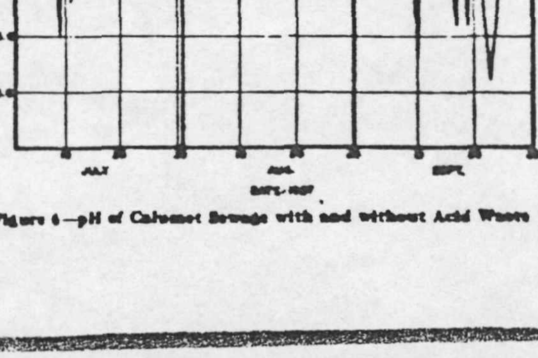

Figure 6—pH of Calumet Sewage with and without Acid Waste

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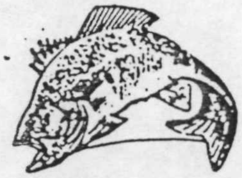

NAME OF WATER	SIZE	MAX. DEPTH (FT.)	SHORELINE LENGTH (MILES)	FACILITIES AND ACTIVITIES									MAJOR SPECIES OF FISH																		LOCATION
				BOAT FISHING	BOAT RENTAL	LAUNCHING RAMP	MOTORS ALLOWED	MOTOR SIZE	SKIING	SWIMMING	CAMPING	PICNICKING	L.M. BASS	S.M. BASS	SPOTTED BASS	BLUEGILL	SUNFISH	CRAPPIE	CHANNEL CATFISH	BULLHEADS	CARP	N. PIKE	WALLEYE	SAUGER	YELLOW PERCH	WHITE BASS	YELLOW BASS	SUCKERS	TROUT	DRUM	
Powderhorn Lake	35	13	1.1									●	●			●	●	●		●	●				●			●			BURNHAM
Turtle Head Lake	12	8	0.7									●	●			●	●		●												3 MI. N.E. OF ORLAND PK.
Papoose Lake*	19	10	0.7									●	●			●											●				1½ MI. W. OF PALOS PK.
Maple Lake	58	20	1.4	●	●							●	●			●	●			●											1½ MI. S.W. OF WILLOW S
Potawatomi Lake	4	9	0.3									●	●				●			●											¼ MI. E. OF WHEELING
Lake Ida	10	15	0.5									●	●			●															2.5 MI. S. OF LA GRANGE
Other Public Lakes																															
Maine Park Lakes												●								●											
East Lake	1	7	0.2									●	●			●	●	●		●											PARK RIDGE
West Lake	1	8	0.1	●	●	●						●	●			●	●	●		●					●						PARK RIDGE
Kimball Hill Pk. Lagoon	1	7	0.2															●		●	●										ROLLING MEADOWS
Lake Michigan Shoreline	—	—	32.4	●	●	●	●		●	●	●	●				●	●	●		●	●				●				●		CHICAGO
Emily Park Lagoon	2	5	0.4									●	●			●			●	●											SKOKIE
Wolf Lake	419	21	6.3	●	●	●	●	10			●	●	●			●	●	●	●	●	●	●			●						CHICAGO
STREAMS:	Miles																														
Salt Creek	17	4																		●	●										
Des Plaines River	44	7		●	●								●			●	●	●		●	●							●			
No. Branch of Chicago R.	16	5		●	●															●	●										
Little Calumet River	24	11		●																●	●				●						
CRAWFORD COUNTY																															
LAKES:	Acres																														
Oblong City Park Lake	6	9	0.6								●	●	●			●	●	●	●	●	●										OBLONG
STREAMS:	Miles																														
No. Fork Embarras R.	4	4		●			●						●			●	●	●	●	●	●			●							
Embarras River	13	15		●			●			●			●		●	●	●	●	●	●	●			●				●		●	
Wabash River	35	40		●		●	●		●	●			●		●	●		●	●	●	●			●		●	●	●		●	
CUMBERLAND COUNTY																															
LAKES:	Acres																														
Lake Mattoon (in part)	329	35	45.0	●	●	●	●	50	●	●	●	●	●			●	●	●	●	●	●							●			3 MI. N. OF NEOGA
Montrose City Lake	8	20	1.0	●								●	●			●			●												3½ MI. N. OF MONTROSE
Lake Toledo	3	10	0.3	●						●		●	●			●			●												TOLEDO
STREAMS:	Miles																														
Muddy Creek	11	8											●			●	●		●	●	●							●			
Embarras River	22	8		●			●							●	●	●	●		●		●							●			
DE KALB COUNTY																															
LAKES:	Acres																														
No. Ill. U. Campus Pond	2	5	0.5										●			●	●			●	●										DE KALB
STREAMS:	Miles																														
Somonauk Creek	13	4									●	●		●		●	●			●	●	●						●			
Indian Creek	12	5									●	●		●		●	●			●	●	●						●			
Little Indian Creek	9	4												●		●	●			●	●							●			
Owen's Creek	6	5												●		●	●			●	●							●			
So. Br. Kishwaukee River	35	6									●	●	●	●	●	●	●		●	●	●	●						●			
DE WITT COUNTY																															
LAKES:	Acres																														
[illegible] Lake	29	28	1.6	●	●						●	●	●			●	●		●	●					●						2 MILES S.E. OF CLINT
[illegible] City Nursing Home L.	5	11	0.7										●			●	●														HALLSVILLE
STREAMS:	Miles																														
Kickapoo Creek	6	4												●		●	●		●	●	●							●			

*Built or Purchased by Illinois Dept. Conservation